MEMS-BASED ARCHITECTURE TO IMPROVE SUBMUNITION FUZE SAFETY AND RELIABILITY

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ABSTRACT

One of the urgent needs in the current and future battlefield is to dramatically improve the reliability and safety of submunition grenades. The ARDEC Fuze Division is developing a MEMS-based safety and arming architecture for submunition fuzes that will so significantly improve the munition's primary reliability that the need for self-destruct (SD) technology will be eliminated. At the same time the safety requirement for transport aboard Navy warships will be met by providing each submunition with a dual-safe safety and arming (S&A) device that must sense a proper launch and expulsion environment.

1. INTRODUCTION

1.1 Background

The current hazardous dud rate of approximately five percent for intentionally-armed DPICM (dual-purpose improved conventional munition) rounds, such as the M77 grenade, degrades lethality and leaves behind a significant hazard to maneuvering forces as well as to post-conflict inhabitants of an exposed area.

The risk becomes greater in situations in which DPICM-loaded rockets and munitions are carried aboard Navy ships prior to theater deployment. During an accidental expulsion of submunition grenades aboard ship, some may become unintentionally armed possibly leading to catastrophic results for the ship. Current measures to incorporate self-destruct technology in future DPICM do nothing to improve primary reliability (function upon target impact) above the ninety-five percent level. They also add cost, and magnify the warship transport scenario since the hazardous duds would function in the self-destruct backup mode. This work was funded by the Marine Corp HIMARS program through ONR.

1.2 Objective and Approach

The ARDEC Fuze Division is developing a MEMS-based safety and arming architecture for submunition fuzes that will so significantly improve the munition's primary reliability that the need for self-destruct (SD) technology, with its associated cost and its safety penalty, will be eliminated. At the same time the safety requirement for transport aboard Navy warships will be met by providing each submunition with a dual-safe S&A that must sense a proper launch and expulsion environment.

The proposed architecture (Figure 1) will fit the current M77 grenade envelope, will retain the stabilizing ribbon and nested slider carriage (though modified), and will incorporate a fully out-of-line firetrain, even after expulsion and slider carriage extension. It will employ a MEMS S&A module to cost-effectively implement a more complex yet robust mechanical safety logic than has heretofore been used.

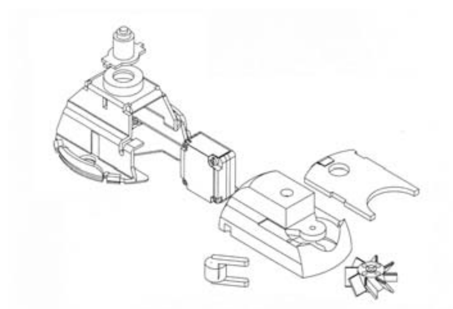

Fig. 1 MEMS-based submunition fuze, exploded view

This electromechanical safety logic will exploit the unique and sequential launch and target environments associated with 155mm projectile- (M915) or rocket- (GMLRS) launch of the submunition carrier. These include launch setback, post-expulsion oriented drag (induced set-forward), airstream-generated energy extraction for fuze circuit power, and target-impact deceleration. Target impact will be sensed with a fast-acting, surface-mounted omni-directional MEMS impact switch. Thus fuze arming, to be realized by the combined electro-mechanical logic, requires a sequential series of environmental inputs very difficult to duplicate unintentionally, even during accidental expulsion on the deck of a ship.

The proposed architecture has the benefit of eliminating unsafe dependencies used in current DPICM fuze technology. There will be no dependence on ribbon spin direction for de-threading a stab bolt. The unreliable moving-bolt stab detonator will be eliminated, which will also dramatically improve safety in handling duds.

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Furthermore the proposed architecture will eliminate the faulty mechanical safety logic of the legacy S&A system, which required only two closely-associated phenomena to occur -- de-nesting of submunitions and turning of the ribbon, plus target impact—for detonation. The resulting system will increase lethality, eliminate the need for SD, reduce battlefield duds to less than one percent, and permit transportation of deployable systems aboard ship.

2. ANALYSIS

2.1 Safety Logic

Fuze safety is controlled by a combination of fuze electronics and mechanical sensors which actuate arming only when the correct magnitude and sequence of environments is detected. Figure 2 details the analysis of the submunition launch-to-target sequence relevant for arming and demonstrates how impervious it would be to failure during an accidental expulsion scenario.

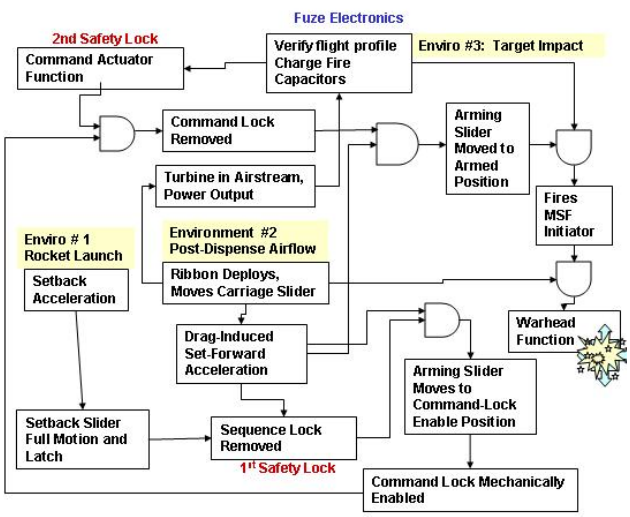

Fig. 2 Safety Logic Flow-chart

2.2 Miniature Air Power Generator (MAPG)

The enabling technology that senses the free-fall air flow of Environment #2 and provides power to the fuze electronics is the MAPG. This miniature turbine device will harness the flow of air to spin a series of magnets through a pick-up coil to generate electrical power. The generated power runs the fuze electronics, charges up the initiator firing capacitor, and provides a flight profile signal to verify the correct free-fall speed and duration for added safety. Figure 3 shows the conversion stages of turbine air-flow power to electrical power in the fuze electronics. Calculations predict an overall power conversion efficiency of 3.4%.

Immediately following expulsion of the submunitions from the delivery vehicle, two environments are

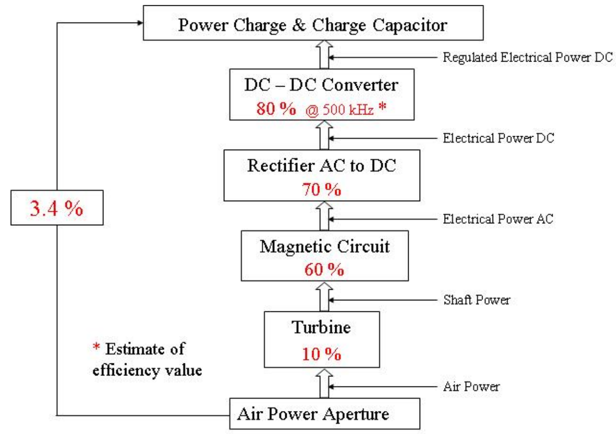

Fig. 3 Power Conversion Efficiency Calculation, MAPG

simultaneously harnessed by the fuze to do work: high-speed air flow turns the miniature turbine to produce electrical power, and air-flow induced drag on the ribbon and body produce deceleration g-forces to enable the removal of the first mechanical safety lock on the arming slider. A threshhold of 14 g's deceleration and 20 mW of generated power for 100-msec is required to remove the mechanical lock and initiate the command actuator. Analysis in Figure 4 shows that even 500 msec after deployment, there is sufficient g's and power available to perform the arming functions.

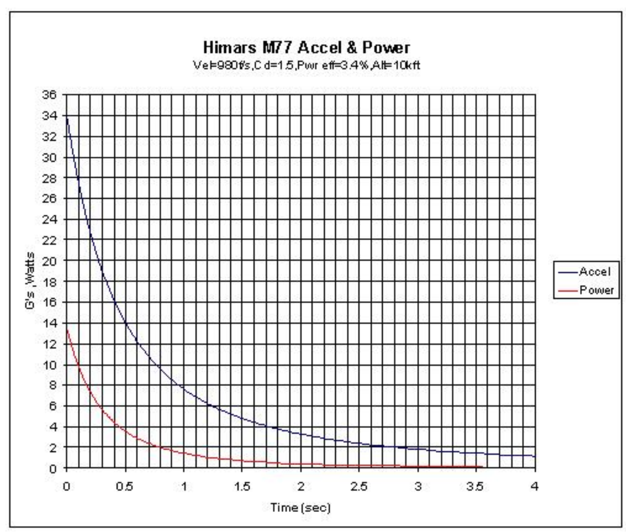

Fig. 4 Accel and Power Vs Time, M77 Submuntion

CONCLUSION

A submunition fuze concept and design, with modelling and analysis, has been generated that will have excellent reliability and will vastly improve submunition safety, especially for shipboard transport. The enabling technologies are a MEMS-based safety and arming device architecture, a MEMS omnidirectional g-switch, and the MAPG.